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FUEL LEVEL CONTROL VALVES/SYSTEMS

1. INTRODUCTION: A fuel level control valve/system controls the quantity of fuel in a tank being filled or emptied. This document provides a general familiarization with these mechanisms (e.g. forms they take, functions, system design considerations). This document provides the aircraft fuel system designer with information about these mechanisms/devices, so that he can prescribe the types of level control valves/systems which are best suited for his particular fuel system configuration.

2. APPLICABLE DOCUMENT: The following publication forms a part of this document to the extent specified herein and is available from SAE, Inc., 400 Commonwealth Drive, Warrendale, PA 15096:

   AIR 1615 - Thesaurus for Fuel System Components

3. TYPES: Generally, it is desired to have a relatively high time-rate-of-change of fuel quantity in fuel tanks, so rather large line sizes and valves are used (up to 6-inch diameter lines and 3-inch diameter level control valves, in some cases). This dictates the use of a large shutoff valve; the most efficient method of controlling this "large" shutoff valve is by the use of a relatively small pilot valve. The pilot valve is directly influenced by the liquid level to be controlled, and the shutoff valve is controlled by the pilot valve. When the shutoff valve and pilot valve are in the same package, it is called an integral level control valve, and, when the pilot valve and shutoff valve are not in the same package, it is called a remote-sensing level control system.

3.1 Types of Shutoff Valves:

Diaphragm Type - The operator is a flexible membrane.

Piston Type - The operator is a piston.

Tank-Mounted - The valve has one port (inlet or outlet) open to the tank. This port will not accommodate the attachment of a conduit.

3.1 (Continued):

Line-Mounted - The valve has inlet and outlet ports both of which can accommodate the attachment of conduits. (Note: this type may be located inside a fuel tank, but it is not a tank-mounted type.)

Normally-Open - This type opens when pressure is applied in the applicable direction. (Note: this type may be closed when at rest with no pressure applied.) The cracking/opening pressure can be specified.

Normally-Closed - This type closes or remains closed when pressure is applied in the applicable direction.

Hydromechanical - Mode control is accomplished by blocking/opening the pilot port(s) or by applying/removing pressure to/from the pilot port(s).

Electromechanical - Mode control is accomplished by introduction/removal of an electric signal.

Plug-In - Refers to types that can be installed/removed into/from tanks or lines without disconnecting the aircraft conduit connections and with minimal leakage from the undrained tanks/lines.

Ø Integral - The shutoff valve and sensing element are in one package (i.e. one part number).

Ø Remote - The shutoff valve and sensing element are in individual packages (i.e. two or more part numbers). The shutoff valve and sensing element(s) are connected by the user.

3.2 Types of Sensing Elements:

Float Valve - A small shutoff valve that gains mode control by submergence or unsubmergence in liquid.

Float Switch - An electric switch that gains mode control by submergence or unsubmergence in liquid.

Fluidic Level-Sensor - A pressure transmitter that transmits pressure when submerged in a gas and does not transmit pressure when submerged in a liquid.

Miscellaneous - Fuel quantity gaging systems can provide electrical signals at predetermined fuel quantities to control the mode of the shutoff valve. Fiber-optic devices discriminate between the indices of refraction of gases and liquids and respond with appropriate electric signals for mode control of the shutoff valve.

4. DEFINITIONS:

AIR 1615 - THESAURUS FOR FUEL SYSTEM COMPONENTS contains many definitions that are applicable to level control valves/systems. The following definitions are those commonly used to describe the design features of level control valves/systems.

4. (Continued):

Operator - The dynamic element which when pressure is applied to it urges the poppet in the desired direction (open or closed).

Overbalance - The ratio of the force (or moment) tending to close the shutoff valve to the force (or moment) tending to open the shutoff valve.

Overshoot - The volume of liquid that passes through the shutoff valve after the shutoff valve has been signaled to close.

Sensing Level - The liquid level at which the sensing element is actuated.

Final Level - The liquid level after final closure of the shutoff valve; this level is a function of the liquid surface area vs. the liquid height above/below the sensing level. This differs from the sensing level because of the influence of the overshoot of the shutoff valve.

Surge-Pressure Relief - Surge-pressure suppression accomplished by limiting the pressure in the operator chamber of the shutoff valve (usually accomplished by the use of a small, spring-loaded relief valve). When this scheme is used, the shutoff valve will reopen when excessive pressure is introduced at the inlet.

Surge-Pressure Control - Surge-pressure suppression accomplished by controlling the flowrate of liquid into the operator chamber in a fashion to control the time-rate-of-change of poppet position with respect to the seat. This scheme is also called "variable-orifice surge control", and, when this scheme is used, the shutoff valve will remain closed when excessive pressure is introduced at the inlet.

Precheck: A feature in level control valves/systems that permits external actuation of the level control valves/systems for checking operation with a non-full tank or for holding the valve closed for some other fuel management consideration.

Negative-"g" - A feature applicable to level sensing devices that brings about a mode change as a result of the reversal of gravitational type acceleration. (Level sensing devices are, by design, orientation-sensitive.)

Pilot Line - The conduit that connects a hydromechanical shutoff valve to a pilot float valve or a fluidic level-sensor.

Pilot Head - The difference in vertical elevation between the elements connected by a pilot line.

Dual - A level control valve/system that has redundant, parallel/series elements that provide mode control independently (e.g. two float valves in the same package controlling two operators that independently operate a single poppet in the shutoff valve).

Fuel-No-Air (Air-Lockout) - A level control valve/system that closes to the passage of gas and opens to permit the passage of liquid.

4. (Continued):

Non-Modulating - A level sensing device that provides controlled changes in response to predetermined liquid levels or has built-in hysteresis such that it opens and closes at significantly different liquid levels.

5. FEATURES OF DIAPHRAGM AND PISTON TYPE OPERATORS:

5.1 Diaphragm Type Operators:

- Least leakage
- Essentially frictionless (excellent for low-pressure operation)
- Can have bi-directional effective-area differences
- Subject to rupture with improper design
- Resistant to particulate contamination
- Effective area varies with axial position
- Guiding not mandatory
- Packaging leads to large-diameter, short valve configuration
- Temperature limited

5.2 Piston Type Operators:

- Very rugged
- Have fixed effective areas
- Have some friction
- Subject to some leakage
- Subject to particulate contaminant damage
- Require guiding
- Resist abnormally high pressures
- Packaging leads to small-diameter, long valve configuration
- Wide temperature range

6. TYPES OF PRECHECK: Precheck of electromechanical systems is usually accomplished by electrically actuating the shutoff valve. The following descriptions are for float-operated, level-sensing devices. It is common to use precheck only in refueling systems; precheck increases system complexity.

Flotation - The float is submerged in liquid by causing a cavity which surrounds the float to be filled. This scheme requires some outside energy (e.g. electricity, fuel flow). This method checks the entire refueling level control system.

Mechanical Override - The pilot valve is mechanically closed. This scheme requires some outside energy (e.g. electricity, pressure). This method checks the entire refueling level control system, except the buoyancy of the float.

7. DESIGN CONSIDERATIONS:

7.1 Pilot Line and Pilot Head (not applicable to integral level control valves):

7.1.1 Long Pilot Lines: Increases the non-fully-open pressure drop of the shutoff valve. May cause throttling, if long enough.

7.1.2 Small-Diameter Pilot Line: Same effects as long pilot line. (The usual minimum is 0.375 inch (9.52 mm) outside diameter x 0.035 inch (0.89 mm) wall.)

7.1.3 Large, Positive Pilot Head (pilot valve higher than shutoff valve): Same effects as long pilot line. Also, increases opening (cracking) pressure of the shutoff valve.

7.2 Shutoff Valve:

7.2.1 Large Operator Diameter: Increases overshoot. Increases non-fully-open pressure drop. Increases closing-force margin. Increases opening (cracking) pressure.

7.2.2 Large Poppet Diameter: Increases envelope required. Reduces pressure drop. Decreases closing-force margin. Reduces opening (cracking) pressure.

7.2.3 Large Control Orifice: Reduces overshoot. Increases surge pressures. Increases non-fully-open pressure drop. Requires larger capacity pilot line and pilot valve.

7.2.4 Low Pressure Drop: Increases envelope. Increases overshoot.

7.3 Pilot Valve:

7.3.1 Flotation Precheck Types: Sensing level may vary with the time-rate-of-change of the liquid level in the tank.